

DECENT: A Decentralized Architecture for Enforcing Privacy in Online Social Networks

Sonia Jahid¹ Shirin Nilizadeh² Prateek Mittal¹ Nikita Borisov¹ Apu Kapadia²

¹University of Illinois at Urbana-Champaign
{sjahid2,mittal2,nikita}@illinois.edu

²Indiana University
{shirnili,kapadia}@indiana.edu

Abstract—A multitude of privacy breaches, both accidental and malicious, have prompted users to distrust centralized providers of online social networks (OSNs) and investigate decentralized solutions. We examine the design of a fully decentralized (peer-to-peer) OSN, with a special focus on privacy and security. In particular, we wish to protect the confidentiality, integrity, and availability of user content and the privacy of user relationships. We propose DECENT, an architecture for OSNs that uses a distributed hash table to store user data, and features cryptographic protections for confidentiality and integrity, as well as support for flexible attribute policies and fast revocation. DECENT ensures that neither data nor social relationships are visible to unauthorized users and provides availability through replication and authentication of updates. We evaluate DECENT through simulation and experiments on the PlanetLab network and show that DECENT is able to replicate the main functionality of current centralized OSNs with manageable overhead.

I. Introduction

Online social networks (OSNs) such as Facebook and Google+ have revolutionized the way people interact and are being used by hundreds of millions of users across the world. However, these designs suffer from a key problem: the lack of user privacy. First, users are not in control of their private data—the social network provider has full access to the user’s data, and, in fact, several providers have been caught selling user data [1]. Second, these networks do not enable a user to set fine-grained policies for access control. For example, users can control access to a status messages in Facebook by using lists (and likewise by using “circles” in Google+), no policy can be defined for comments and actions such as “likes” or +1’s. The problem is further exacerbated by the network provider’s constantly changing and oblique privacy policies [2]. Recent accidental and malicious privacy breaches have further motivated designs that enable social networking with privacy preservation [3]–[5].

Unfortunately, alternative proposals to improve user privacy in OSNs do not provide an adequate level of privacy. Proposals for centralized designs [6] either trust the OSN provider with user data and/or allow the provider to perform effective traffic analysis attacks to undermine user privacy by, for example, learning a user’s social contacts. Users consider their social contacts to be sensitive information,

evidenced by the public outcry when Google Buzz made this information public, and was forced to change its default settings [7]. Alternative decentralized designs [8]–[11] remove reliance on a central entity, but have not adequately tackled confidentiality and access control issues.

We propose DECENT, an architecture for enforcing access control in a decentralized OSN. Our focus is on providing data confidentiality, integrity, and availability in the presence of malicious nodes in a distributed setting. Our architecture is also able to protect the privacy of user relationships. DECENT is based around a flexible object-oriented design (OOD) that supports the main functionality of OSNs and captures the complex multi-principal interactions that are common in social networks. The confidentiality and integrity of data are protected by a cryptographic mechanism so that they can be stored in untrusted nodes in a distributed hash table (DHT). The standard DHT mechanisms are extended to ensure availability despite malicious attempts to erase or overwrite stored data.

Our contribution in this paper is twofold:

1) Design: We propose a decentralized OSN architecture that: i) provides flexibility in data management through OOD; ii) uses an appropriate and advanced cryptographic scheme that supports efficient access revocation and fine-grained policies on each piece of data; and iii) combines confidentiality, integrity, and availability by using the functionalities of a DHT—all the existing designs focus on one or two, but not all of these aspects. The novelty of our architecture lies in integration of existing primitives that are tailored to enhance the security and privacy of OSNs.

2) Prototype: We develop a prototype of DECENT—the wall and newsfeed functionalities, to be specific—and evaluate its performance through simulation and experiments on PlanetLab. We evaluate DECENT using a FreePastry simulator and a Kademia implementation on PlanetLab [12], [13]. Our preliminary analysis shows that the performance overhead of DECENT is acceptable, and that our architecture for privacy-preserving decentralized OSNs is feasible. For example, although a wall with 60 objects needs 90s to be viewed by its owner, contents can be displayed progressively; i.e., older messages can be fetched while the user is reading the most recent messages, which are loaded within the first few seconds. We are currently investigating

techniques to further improve performance through cryptographic optimizations [14]. Our architecture thus demonstrates that existing security primitives with well understood properties can be leveraged to provide a compelling privacy-preserving alternative to centralized OSNs.

II. Requirements and Properties

A. Functional Model

Much of the functionality of OSNs can be described as users posting content and their social contacts viewing, commenting on, and annotating such content. To provide a flexible, general model of these operations, we define a *container object* that has two components: the main content and a list of comments/annotations, represented as references to other container objects. The main content can take on many types, such as a status update, a shared link, a photo or video, or a collection of container objects (e.g., a photo album). For our purposes, the content type is not important; the key difference is that the *access permissions* on the comments can be more restrictive than the content to enforce the policy of each object and owner individually.

A user’s profile is a root object, which contains references to other objects, such as contact information, a wall, photo albums, etc. Similarly, other objects may consist of some content and references to other objects. For example, a wall may have references to status messages and posts where a status/post object may contain references to comment objects in addition to the status data. Thus, each user’s content is organized in a hierarchical fashion (although we do not enforce a tree structure—a single object may be referenced by multiple “parent” objects). With this degree of granularity in our object design, access permissions can be assigned specifically for each object and then referenced by other containers.

B. Security Requirements

Within this model, we can outline a number of security and privacy requirements:

Confidentiality: Preserving the confidentiality of user content is a key requirement for a decentralized OSN. Content should be accessible to only those who are explicitly authorized by the content owner. Furthermore, nodes hosting such data may themselves not be authorized to read the data.

Integrity: We must also ensure the integrity of the data so that OSN users can be certain that content posted by their friends is authentic. This property is important in a peer-to-peer network since storage nodes are untrusted and may try to perform unauthorized updates to the stored data.

Availability: User content should remain available until it is explicitly deleted by its owner, even if the owner is offline, and despite potential malicious attempts to destroy the data. Readers should also be able to retrieve the most recent version of a content object rather than past ones.

Explicit Owner-specified Access Control: Policies controlling who may view, modify, or comment on content are defined by its owner and cannot be changed without the owner’s authorization.

Relationship Privacy: Relationships between users should remain hidden from third parties that may have no relationship with the object owner and are therefore untrusted, such as storage nodes.

C. Threat Model

We assume that the participants in the decentralized OSN may be malicious (or compromised) and therefore should not be trusted with the confidentiality and integrity of data and relationship information. Moreover, the malicious entities are considered to be Byzantine, and can launch both active and passive attacks. Distributed systems are vulnerable to the problem of Sybil attacks, where a single entity can obtain multiple identities in the system and violate security properties. We assume the existence of mechanisms to defend against the Sybil attack [15], [16]. We consider that up to 25% of the nodes in the system can be malicious, since, beyond that, existing mechanisms [15] are not able to securely route in distributed hash tables, which is a necessary prerequisite to provide both integrity and availability guarantees. In peer-to-peer networks, malicious nodes may attempt to launch denial of service (DoS) attacks against honest peers, by overwhelming their network, computational, or storage resources. We assume existence of defenses against such DoS attacks [17], [18]. In this paper we focus on the cryptographic mechanisms to protect the security of stored data, rather than on routing-based attacks or DoS attacks, which can be addressed by existing mechanisms, and which we will therefore not discuss further.

III. System Architecture

DECENT is a decentralized OSN, which employs a DHT to store and retrieve data objects created by their owners. Each object is encrypted to provide confidentiality. The primary advantage of our architecture is its modularity, i.e., the data objects, the cryptographic mechanisms, and the DHT are three separate components, interacting with each other through well-defined interfaces. The modular design allows us to separate the various cryptographic implementations (ABE, signatures) from the basic object model (container objects, permissions, etc.) and use any type of DHT.

A. Access Policies

Each object has three access policies associated with it. The policies are either attribute-based (AB), identity-based (IB), or a combination of both types. AB policies take the standard form of policies described through various attributes, for example, *friend*, *family*, *coworker*. AB policies can represent formulas over attributes, using operators such as \wedge , \vee , and *k-of-n*. Examples of AB policy are: (*friend* \wedge

coworker) \vee family, and 2 of {friend, family, coworker} (background on Attribute-based Encryption (ABE) is provided in section III-B).

- Read policy (*R-Policy*) describes who may read the contents of the object. It is an AB policy that describes the attribute combination required for a user to decrypt an object's data.
- Write policy (*W-Policy*) describes who may modify the contents of the object or delete the object. It is an IB policy, which generally is set to the owner of the object.
- Append policy (*A-Policy*) describes who may add a comment/annotation to the object. It is also an AB policy.

These policies are defined by the owner at the time of object creation and are stored in the object metadata. The read policy is enforced through the use of cryptography. The write and append policies are enforced through a combination of cryptography and specialized DHT functionality. A reader can cryptographically verify the integrity of the object and be sure that the content and comments have been posted by parties authorized by the write and append policies, respectively. Additionally, the DHT storage nodes require authorization before each write operation to prevent malicious deletions and vandalism. The authorization does not reveal a user's identity, hence the storage node is not aware of the identities of users storing or retrieving data from it, and therefore a user's social graph is hidden from the storage nodes. DHT nodes also implement a special append operation that adds a new annotation to the object while leaving existing content unmodified. When objects are being stored at malicious nodes, confidentiality is still preserved due to cryptography. However, the malicious nodes can impact the integrity and availability guarantees by deviating from the protocol, e.g., by deleting objects and/or returning previous versions of objects. Malicious nodes in the DHT can be tolerated using replication.

B. Cryptographic Protection

Objects are stored on untrusted DHT nodes, thus necessitating the use of cryptography to protect their confidentiality and integrity. For confidentiality, Baden et al. [19] observed that ABE [20] is a good fit for OSNs because it allows users to specify access policies in terms of groups of contacts, such as friends, family, coworkers, etc. We adopt several modifications to the base ABE to better satisfy our security requirements.

Confidentiality: Attribute-based encryption is a public-key encryption scheme where each encrypted item is associated with a policy. There are many decryption keys, and each one is associated with a set of attributes. A key can decrypt an encrypted item if its set of attributes satisfies the item's policy. A key authority (KA) maintains the master secret key (MSK) and can generate decryption keys with an arbitrary set of attributes. In the OSN context, each user

becomes a key authority, issuing different encryption keys to social contacts based on their attributes. The social contact will know which attributes identifiers they possess, but not their semantic meaning.

Like most public-key schemes, ABE is usually used in hybrid encryption mode, wherein the message is encrypted with a randomly chosen symmetric encryption key, which is in turn encrypted with ABE. We follow this approach with a modification that the ABEncrypted symmetric key is in fact part of the object reference and not included in the object itself. The main motivation for this choice is that the version of ABE we are using lacks policy privacy and this approach keeps the policy hidden from untrusted storage nodes. The reference is a part of the parent object and is encrypted with its symmetric key. As a result, the reference cannot reveal the policy.

An additional consequence of this approach is that when several references for an object exist, the object may have different read policies associated with it. For example, if Bob posts a comment on a status update on Alice's wall, he may wish to add a reference to his comment (or even the status update) to his own wall so that it can be seen by his contacts.¹ In this case, Bob's comment may be visible to some subset of Alice's contacts when reached through her status update, and some subset of Bob's contacts when reached through his wall.

A second extension of ABE is the support for immediate revocation by the use of the EASiER scheme [21]. From time to time, a user may wish to revoke one or more attributes from a social contact. An ideal revocation scheme would ensure that the revoked contact can no longer access any data that requires the revoked attribute(s), including existing data. To support this, EASiER makes use of a proxy in every decryption. In brief, decryption keys in EASiER are blinded in a way specific to each user's identity; to decrypt a data item, a user with the appropriate key must contact the proxy to transform the ciphertext so that it is compatible with the blinded key. When Alice wishes to revoke an attribute, she updates the proxy key in such a way that this transformation is no longer possible for the revoked users. The proxy itself is minimally trusted—it can neither decrypt the data nor restore access for a previously revoked user even if it is compromised.

We propose two extensions to the base EASiER scheme. First, threshold secret sharing can be used to split the proxy functionality among several randomly selected nodes; since we assume that the majority of nodes are not actively malicious, it will ensure the security of the proxy. With (t, n) threshold proxies ($t < n$), $t + 1$ out of n proxies need to be malicious, i.e., colluding with the decryptor, to

¹Note that this may contravene Alice's privacy wishes, but no architectural protection short of DRM can prevent Bob from such re-sharing. A possible mitigation strategy is to issue a warning to Bob about the possible privacy breach, as is currently implemented in Google+.

allow a revoked user to decrypt data. Second, EASiER can be extended to support attribute delegation: if Alice issues a key with a set of attributes to Bob, Bob can delegate a subset of these attributes to Carol. This way, Alice can define a “friend-of-a-friend” attribute and ask all her contacts to delegate it to all of their contacts. Note that Carol will have to use both Alice’s and Bob’s proxies for decryption, so if either Alice revokes Bob’s access or Bob revokes Carol’s, the decryption will fail. These extensions will be described in an upcoming technical report.

Integrity: To protect the integrity of the object, we make use of digital signatures. The owner of the object digitally signs its contents and metadata, excluding the list of comments; each comment reference is signed individually using a different signature key. The write and append policies are implemented by controlling access to the corresponding secret signature keys, which act as *capabilities*, similar in spirit to Tahoe-LAFS [22]. The append-policy secret key is encrypted with an ABE policy; the write-policy key can be encrypted with conventional encryption since it typically needs to be accessible by a single person (the object owner). Both public keys are stored as part of the object metadata, but the write-policy public key must be replicated as part of the object reference to ensure its authenticity; the append-policy public key is authenticated by the write-policy signature. An object reference, therefore, consists of:

$$objRef \stackrel{\text{def}}{=} (objID, ABE(K, P), WPK)$$

where *objID* is a random object identifier, used to locate it in the DHT, *K* is the symmetric key used to encrypt the referenced object, *P* is the attribute-based read policy, and *WPK* is the write-policy signature public key. As an optimization, $ABE(K, P)$, the ABEncrypted symmetric key, can be replaced by an unencrypted *K* if the read policy of the referenced object matches the container.

C. Distributed Hash Table

Participants in the OSN are organized into a distributed hash table (DHT), such as Pastry [12] or Kademia [13]. The DHT creates a scalable key-value store with an efficient lookup mechanism to locate nodes that store a given object. DHT lookups can be made secure against attacks [15], ensuring that a lookup will find the correct copy of an object if it exists. (It may additionally find incorrect copies provided by malicious nodes; cryptographic integrity protection described above can be used to identify the correct one.)

Objects in DECENT are stored in the DHT using the *objID* as the key. To ensure availability despite node churn and malicious attacks, several replicas of an object are maintained. DHTs typically use the neighbor set of the node responsible for the object key to maintain replicas; the number of replicas needs to be tuned based on the churn patterns of the network (malicious nodes can also be modeled as churn in this case), which we will study in our

future evaluation. To guarantee freshness, each object has a version number as part of its metadata. The version number is authenticated by the write-policy signature, thus a user can query all of the replicas and use the freshest object returned.

Malicious users may try to modify or delete an existing object. Note that the write policy prevents them from creating modifications that will be accepted by the readers, as they cannot produce a correct signature, but they may overwrite and destroy legitimate data. To address this, the write-policy public key is stored unencrypted as part of the object metadata. The storage node will refuse to overwrite the stored object unless the new data is properly signed by the write-policy key; deletions must likewise be authenticated with a signature. Thus, as long as there is always at least one honest (but curious) replica for an object, it will persist despite any malicious attacks. The write-policy public key *should not* be a user’s permanent public key, as otherwise a storage node could use it to link an object to its owner. Instead, a separate *WPK* is generated for each object, ensuring unlinkability of objects. A copy of the corresponding secret key (*WSK*) is stored in the object, encrypted with the owner’s secret key. We use the Digital Signature Algorithm (DSA) for write-policy signatures because it allows new keys to be generated very quickly.

In addition to the standard *get* (read) and *put* (write) requests, the DECENT DHT supports an *append* request, which is used to add a comment reference to an existing object. As with write requests, the storage node verifies that the append carries the correct signature from the append-policy key, using the public key (*APK*) that is stored in the clear as part of the object.

D. Example

Join: To join DECENT, Alice sets up her profile, wall, and keys. She generates her ABE public and master secret keys and signature key pair. Alice creates an object with her profile information, encrypts it with a symmetric key, and signs it with her write-policy signature key SPK_{Alice} . She generates a random ID, saves her profile in the DHT using this ID, ABEncrypts the symmetric key with profile R-policy, and creates a reference to the profile object. Similarly, she sets up her wall. Alice can be reached through the reference to a root object, which contains the references to her profile and wall. The root object acts as another regular object and is stored in the DHT. The root object can be thought of a user’s landing page on Facebook.

Establish Contacts: To establish the relationship *friend*, *co-worker* with Bob, Alice generates an ABE secret key for Bob with the attributes *friend*, *co-worker*. Relationships are asymmetric, so Bob may establish just *acquaintance* relationship with Alice by issuing an ABE secret key for this attribute. Keys are exchanged out of band. Alice and Bob also exchange their root object references.

Post and Comment: Figure 1 shows an example object structure. When Alice wants to post a status update to her wall, she creates the status update object, complete with version number, contents, and public and secret keys for the write and append policies ($WPK_1, WSK_1, APK_1, ASK_1$). She then generates a signature over the write-policy signature key (WSK_1). She then picks a random symmetric encryption key K_1 and encrypts the object (except for WPK_1 and APK_1 and the signature); she also chooses a random id ID_1 and uses this to insert the object into the DHT. Finally, she creates a reference to the status update, including ID_1, K_1 and her write-policy public key (WPK_1) and adds it to her wall. K_1 is encrypted with an attribute-based policy P_1 , which governs who can read the status update. Note that Alice’s wall will also be encrypted with a symmetric key K_0 , which is part of the reference to Alice’s profile that she gives to her friends.

When Bob wants to read Alice’s update, he finds the reference on Alice’s wall and decrypts K_1 with his attribute-based secret key that he got from Alice, assuming that his attributes satisfy the policy P_1 . Note that Bob has to satisfy the R-Policy associated with the wall object itself to get access to the reference. He then retrieves the object from the DHT with the key ID_1 and decrypts the encrypted fields using K_1 . Finally, he verifies the signature to ensure the authenticity of the object.

If Bob further wants to comment, then he first creates a comment object following a process similar to Alice’s creation of her update. He then uses the *append* operation to insert a reference to the new object into Alice’s update. Assuming he satisfies the A-policy AP_1 , Bob decrypts ASK_1 and uses it to generate a signature on the reference. The encryption key K_2 is further ABEncrypted using Bob’s policy P_2 ; thus, only users who satisfy both P_1 and P_2 will be able to read the comment.

IV. Implementation and Evaluation

We have implemented a preliminary prototype of DECENT, which provides functionality similar to the Facebook wall. It also provides a basic newsfeed option, summarizing status updates from a person’s contact/friend list. We use four different types of cryptographic schemes in DECENT: EASiER for ABE, AES for symmetric encryption, DSA for signatures, and RSA to encrypt the write policy signature key. We use a combination of EASiER and DSA to realize ABS. The key sizes are chosen as recommended by NIST [23] for maximum security. We use FreePastry with Euclidean network topology for simulation, and Kademia [24], [25] for the experiments on PlanetLab as the underlying DHT. Our proxy was run on a standard server for simulation and PlanetLab experiments.

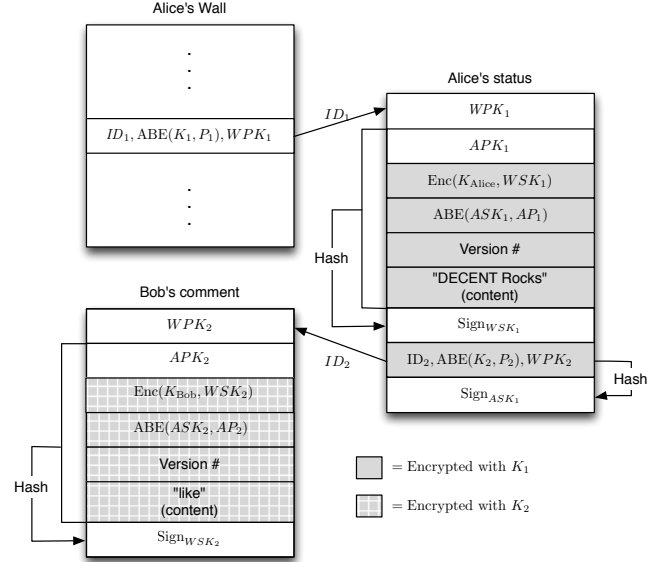


Figure 1: Example objects

A. Simulation

We perform experiments to measure the performance of viewing a user’s newsfeed and wall with varying numbers of status messages, posts, and comments. The simulation was run on a peer-to-peer network of 10 000 nodes. Figure 2 shows our simulation results.

View Wall: To view a wall, a user uses the wall reference to fetch the wall object, ABDecrypts the wall reference to get the AES key to decrypt the wall object, and gets the wall metadata and the references to statuses and posts. Each reference is used to fetch the corresponding status or post. The user ABDecrypts the reference to view the content of the object.

We perform tests to view wall with: 1) only statuses, 2) statuses and same number of posts from friends, and 3) statuses, posts, and one comment on each status from friends. Figures 2a and 2b show results for viewing one’s own wall and friends’ walls respectively. A data point such as x statuses means that when a user views a wall that contains statuses, posts, and comments, she views x of each, i.e., $3x$ objects.

We allow users to cache the AES encryption keys for the objects they create and thus avoid ABDecryption of the references to their own objects. Therefore, viewing one’s own wall with only statuses is much faster than viewing a friend’s wall with only statuses. Viewing one’s own wall with statuses and posts involves ABDecryption for the posts from friends and only AESDecryption for the statuses. The same applies to comments from friends. When a user has not posted anything herself to her friends’ walls, then viewing friends’ walls involves ABDecryption for each item on the wall, and so represents the worst case scenario.

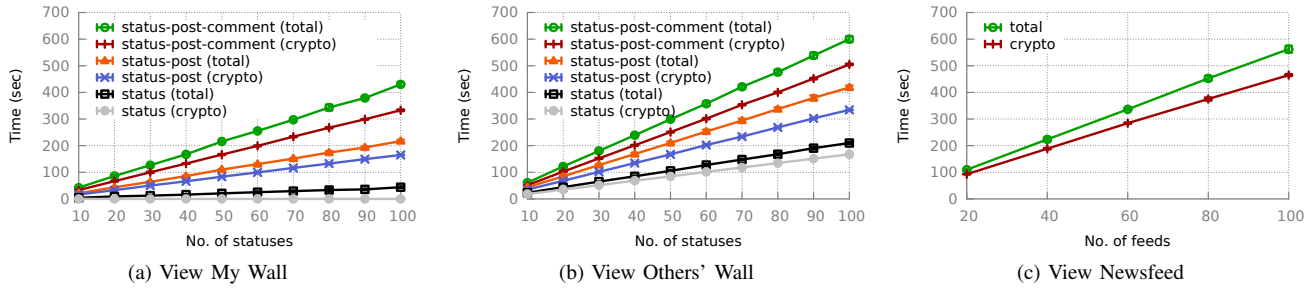


Figure 2: Simulation Results for 10,000 nodes: The average time to view another user’s wall with 10 and 20 status/post/comments is about 60 s and 120 s respectively. The average time to view a newsfeed with 20 peers is 109 s.

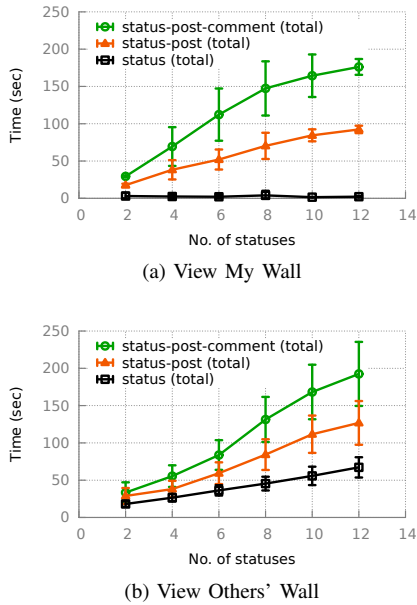


Figure 3: PlanetLab Results: The average time to view another user’s wall with 10 status/post/comments is about 168 s.

The current view time (e.g., 90 s to view a user’s own wall with 20 statuses, 20 posts, and 20 comments) may appear large; however, content can be displayed progressively, and thus older messages can be fetched while the user is reading the most recent messages, which are loaded within the first few seconds. We are also currently working on cryptographic optimizations to speed up these operations.

View Newsfeed: We test our prototype to evaluate the basic newsfeed functionality. This approach fetches the latest status from each of a user’s friends. Figure 2c shows the results. An example newsfeed with 40 feeds takes around 215 s to construct and view. The results will be improved with parallel lookups and decryption. However, in current OSNs a user’s newsfeed generally shows 20–30 posts at a time. Some techniques, such as showing feeds in blocks and

pre-fetching the latest updates from friends while the user is offline, will improve the performance. We will investigate these techniques in our future evaluation.

Post and Comment: To post/comment on another user’s wall, a user signs the reference to the post or comment with the append-policy signature key of the parent object, which she ABDdecrypts from the parent object. The average time to post or comment is 3.94 s. The results are reasonable since a user can continue her OSN activities while the update is performed.

B. Experiments on PlanetLab

We perform the same experiments on 15 PlanetLab nodes to get an idea of DECENT’s performance in a real deployment. Currently, the DHT has been implemented on PlanetLab using a Kademia prototype extracted from the Likir implementation [25]. Figure 3 shows the results of our preliminary PlanetLab experiments. As expected, the time to view walls in PlanetLab machines takes slightly longer because of network delays, such as the communication between peers and the proxy. In addition, because of node failures, a few of the users’ walls could not be viewed, and in some experiments, walls were retrieved only partially. We also test the time to construct and view the newsfeed. A newsfeed with 11 feeds takes 37.3 s (95% confidence interval is [34.4, 40.1] s), which closely resembles our simulation results. For improved performance and resilience, we are investigating the use of caching and replication parameters, which will be reported in subsequent work.

V. Related Work

Several projects such as Diaspora [9], PeerSon [8], Safebook [11], and LotusNet [10] have addressed privacy in OSNs either through cryptography, architectural modifications, or decentralization of the provider.

Diaspora is a social network that users install on their own personal web servers, without support for encryption. Backes et al. [26] present a core API for social networking, which can also constitute a plug-in for distributed OSNs. However, they assume that the server is trusted with the

data while implementing access control protection. PeerSon, LotusNet and Safebook benefit from DHTs in their architecture. PeerSon and Safebook suggest access control through encryption, but they fall short in providing fine-grained policies comparing to ABE-based access control. Moreover, in all of these schemes overhead of key revocation affects performance. Safebook is based on a peer-to-peer overlay network named “Matryoshka”. The end-to-end privacy in Matryoshka is provided by leveraging existing hop-by-hop trust. In LotusNet, which is based on Likir [24], the authors consider the distributed storage to be trusted and do not perform encryption. Likir uses signed grants to specify permissions and provide access control.

The closest work to DECENT is Persona [19] that combines ABE with a decentralized OSN architecture to ensure data confidentiality. However, Persona falls short while supporting the fine-grained policy required for OSNs, because the underlying cryptographic mechanism [20] lacks efficient revocation. DECENT uses an extended version of EASiER [21] with support for access delegation while providing extremely fine-grained access control. In addition, DECENT provides user-verifiable data integrity using digital signatures. Persona is not built upon a DHT; the storage service in Persona authenticates write operations through the requester’s public key and hence can learn the user’s social contacts. DECENT solves this issue through carefully designed cryptographic techniques. Besides, unlike Persona, DECENT separates the policy used to encrypt the data from the ciphertext itself, thus preventing the storage nodes or a third party from inferring a user’s privacy policies by getting access to a ciphertext. Persona uses a multi-reader-writer service for the wall, but lacks a protocol for commenting on wall posts. DECENT provides a full design and implementation to read, write, and comment on walls or any data that appears on a wall.

VI. Conclusion and Future Work

In this paper we proposed DECENT, a design for decentralized social networks with an emphasis on security and privacy. DECENT uses an efficient cryptographic mechanism for confidentiality, combining traditional and advanced cryptographic schemes for integrity, and the use of a DHT for availability. We discussed the architecture in detail, and presented a prototype of our design. Simulation and experiments on PlanetLab with our preliminary prototype show that a privacy-enhanced OSN based on DHT with focus on confidentiality and integrity is a feasible architecture. Our future work includes adding features to DECENT and further improving performance and resilience through optimized cryptographic techniques, caching, and replication.

References

[1] E. Steel and J. E. Vascellaro, “Facebook, MySpace confront privacy loophole,” *The Wall Street Journal*, May 2010.

[2] K. Opsahl, “Facebook’s eroding privacy policy: A timeline,” <https://www.eff.org/deeplinks/2010/04/facebook-timeline>.

[3] M. Cha, A. Mislove, B. Adams, and K. P. Gummadi, “Characterizing social cascades in Flickr,” in *WOSN*. ACM, 2008.

[4] R. Gross and A. Acquisti, “Information revelation and privacy in online social networks (the Facebook case),” in *WPES*, 2005.

[5] E. Steel and G. A. Fowler, “Facebook in privacy breach,” *The Wall Street Journal*, Oct. 2010.

[6] K. Singh, S. Bhola, and W. Lee, “xBook: Redesigning privacy control in social networking platforms,” in *USENIX Security Symposium*, 2009.

[7] R. Waters, “Google seeks to quell Buzz privacy outcry,” *Financial Times*, Feb. 2010.

[8] S. Buchegger, D. Schiöberg, L. H. Vu, and A. Datta, “Peer-SoN: P2P social networking — early experiences and insights,” in *SNS*, 2009.

[9] “Diaspora*,” <https://joindiaspora.com/>.

[10] L. Aiello and G. Ruffo, “LotusNet: tunable privacy for distributed online social network services,” *Computer Communications*, vol. 35, no. 1, pp. 75–88, 2012.

[11] L. A. Cuttillo, R. Molva, and T. Strufe, “Safebook: Feasibility of transitive cooperation for privacy on a decentralized social network,” in *WOWMOM*, 2009.

[12] A. Rowstron and P. Druschel, “Pastry: Scalable distributed object location and routing for large-scale peer-to-peer systems,” in *Middleware*, 2001.

[13] P. Maymounkov and D. Mazières, “Kademlia: A peer-to-peer information system based on the xor metric,” in *IPTPS*, 2002.

[14] M. Green, S. Hohenberger, and B. Waters, “Outsourcing the decryption of ABE ciphertexts,” in *Usenix Security*, 2011.

[15] M. Castro, P. Druschel, A. Ganesh, A. Rowstron, and D. Wallach, “Secure routing for structured peer-to-peer overlay networks,” in *OSDI*, 2002.

[16] C. Lesniewski-Laas and M. F. Kaashoek, “Whanau: a Sybil-proof distributed hash table,” in *NSDI*, 2010.

[17] D. Dumitriu, E. Knightly, A. Kuzmanovic, I. Stoica, and W. Zwaenepoel, “Denial-of-service resilience in peer-to-peer file sharing systems,” in *ACM SIGMETRICS*, 2005.

[18] I. Osipkov, P. Wang, and N. Hopper, “Robust accounting in decentralized P2P storage systems,” in *ICDCS*, 2006.

[19] R. Baden, A. Bender, N. Spring, B. Bhattacharjee, and D. Starin, “Persona: an online social network with user-defined privacy,” in *ACM SIGCOMM*, 2009.

[20] J. Bethencourt, A. Sahai, and B. Waters, “Ciphertext-policy attribute-based encryption,” in *IEEE Security & Privacy*, 2007.

[21] S. Jahid, P. Mittal, and N. Borisov, “EASiER: Encryption-based access control in social networks with efficient revocation,” in *ASIACCS*, 2011.

[22] Z. Wilcox-O’Hearn and B. Warner, “Tahoe: the least-authority filesystem,” in *StorageSS*, 2008.

[23] E. Barker, W. Barker, W. Burr, W. Polk, and M. Smid, “Recommendation for key management—part 1: General (revised),” NISsT, Tech. Rep. SP800–57, 2007.

[24] L. M. Aiello, M. Milanesio, G. Ruffo, and R. Schifanella, “Tempering Kademlia with a robust identity based system,” in *P2P*, 2008.

[25] —, “An identity-based approach to secure P2P applications with Likir,” *Peer-to-Peer Networking and Applications*, vol. 4, pp. 420–438, 2011.

[26] M. Backes, M. Maffei, and K. Pecina, “A security API for distributed social networks,” in *NDSS*, 2011.